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FISH COMMISSION OF OREGON
307 State Office Building
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Volume Six—Number One

NOVEMBER 1955

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FOREWORD

These short reports are intended to inform the public, industry, and other interested parties of the current studies of the Commission's saff and of the basis for conservation measures. Reports will be published from time to time when studies are sufficiently complete to provide reliable biological evidence for conclusions upon which regulations are based. Research Briefs are free and may be obtained upon request from the editor.

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TABLE OF CONTENTS

Page

The Intertidal Mussel, Piddock, and Abalone Resources of Oregon's Outer Coast ..... **James E. McCauley** and **Lowell D. Marriage** 4

The Transfer of Hatchery Fish to Estuarine Waters ..... **John T. Gharrett** 14

Escapement of Spring Chinook Salmon and Steelhead Over Willamette Falls in 1953 ..... **Earl F. Pulford** 19

Fourth Progress Report on Salmon Diet Experiments ..... **James W. Wood, Wallace F. Hublou, Thomas B. McKee, Russell O. Sinnhuber,** and **Duncan K. Law** 29

Migrations of Starry Flounder (*Platichthys stellatus*) Tagged in the Columbia River ..... **Sigurd J. Westrheim** 33

Past issues of the Research Briefs include: Vol. 1, Nos. 1 and 2; Vol. 2, Nos. 1 and 2; Vol. 3, Nos. 1 and 2; Vol. 4, No. 1; Vol. 5, No. 1. Beginning with this issue the title will be changed from Fish Commission Research Briefs to Research Briefs, but the numbering will continue in the present sequence.

THE INTERTIDAL MUSSEL, PIDDOCK, AND ABALONE RESOURCES OF OREGON'S OUTER COAST

JAMES E. McCAULEY①
LOWELL D. MARRIAGE

Introduction

A survey of the molluscan resources of the intertidal zone along the outer coast of Oregon has not been attempted since the survey by Edmundson in 1920. Although Twohy (1949) reviewed the razor clam sport fishery and Marriage (1954) reviewed the bay clam fishery, nothing has been published concerning the rock-dwelling forms of the outer coast. Shellfish of probable economic importance on the outer coastal rocks fall into the general classes of mussels, piddocks, and abalones. This paper is concerned primarily with the distribution of these forms with notes on accessibility, general abundance, and utilization as observed during the summer of 1953.

Mussels of the family Mytilidae have been reported on the outer coast. *Mytilus californianus* Conrad, the California mussel, is the dominant form. This species as well as *M. edulis* Linnaeus, the bay mussel, was reported by Edmundson (1920). The giant horse mussels, *Volsella modiola* (Linnaeus) and *V. flabellata* (Gould); the smooth pea-pod borer, *Botula californiensis* Philippi; and the rough pea-pod borer, *B. falcata* Gould, are other members of this family to be found in Oregon (Oldroyd, 1924).

Piddocks or rock oysters of the family Pholadidae have been observed. The flap-tipped piddock, *Pholadidea penita* Conrad, was reported by Edmundson (1920) from Nye Beach, which he states to be the locality of greatest abundance. Dore (1891), in a survey of mollusks in the Portland, Oregon, market, reported an occasional shipment of rock oysters, *P. penita,* received at Portland and gathered at the entrance to Yaquina Bay. Oldroyd (1924) includes Oregon within the ranges of *P. penita, P. ovoidea* Gould, *P. rostrata* Valenciennes, and *Zirfaea pilsbryi* (Tryon). The small piddock, *P. parva* Tryon, has been found embedded in the shell of the red abalone, *Haliotis rufescens* Swainson, in central California, but the authors found no published records of this species from Oregon (Burch [Ed.], 1945).

Bonnot (1948) includes Oregon within the ranges of the black abalone, *H. cracherodii* Leach, and the Japanese abalone, *H. kamschatkana* Jonas. Oldroyd (1924) also notes that only these two species occur along the Oregon coast. Local residents report the red abalone, *H. rufescens,* occurs on the southern beaches of Oregon. However, the authors found no published records of this species occurring in Oregon.

During the course of the survey, detailed information was kept as to the type of beach, rocky or sandy, and the accessibility. Oregon's coastline is approximately 316 miles long, as measured on U. S. Corps of Engineers quadrangle maps. Sandy beaches account for 76 per cent (240 miles) and rocky beaches 24 per cent (76 miles). All sandy beaches were accessible either by publicly used roads or trails and 61 per cent (146 miles) of these were 1 mile or less from the end of the nearest access

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road. Only 56 per cent (43 miles) of the rocky beaches were accessible by publicly used road or trail and 38 per cent (29 miles) of the rocky beaches were 1 mile or less from the end of the nearest access road. Considering all beaches, rocky and sandy, 90 per cent (284 miles) were accessible and 56 per cent (177 miles) were within 1 mile or less from the end of the nearest access road.

Materials and Methods

Information for this report was derived from interviews with residents or others familiar with the area in question, and physical surveys by the authors. The surveys generally consisted of two types. The first was preliminary, at no particular tide level, and served primarily to determine accessibility of the beds in question. The second was undertaken at a low tide level to check on accessibility and abundance of the shellfish.

Local residents provided information concerning the location and accessibility of the various beds. The piddock beds at Nelscott and Newport were located in this manner. In a few cases when limitation of time prevented a physical survey, reports of residents were accepted, if substantiated by uniformity of two or more accounts.

The areas mentioned throughout the report may be located on the chart of Oregon's coastline presented in Figure 1.

Mussel Surveys

The California mussel, *M. californianus*, appears on the Oregon coast at almost every point where there are rocks large enough for it to gain a foothold (Figure 2). Relative abundance, size, and accessibility were considered in determining the beds of economic importance. Mussels were considered abundant if all suitable rocks were blanketed with a layer of them, and scarce if all suitable rocks had only scattered specimens attached. Although California mussels grow to 10 inches in length (Fitch, 1953), individuals 5 inches and over are considered large for the purpose of this discussion. The following discussion of mussel beds by area is considered from north to south along the coast.

The Tillamook Head area is largely inaccessible. It is possible to get to the rocks along the northern edge, near Seaside, and at Indian Point and Ecola Point. A large number of accessible mussels were noted at Ecola Point and it is possible that there are large numbers on the inaccessible, outer part of the head. Mussels are present on Haystack Rock at Cannon Beach (5 miles south of Tillamook Head) and on some of the other rocks nearby. On the rocks at Silver Point, midway between Tillamook Head and Cape Falcon, it is possible to drive an automobile on the beach close enough to the mussel-bearing rocks to gather mussels through the car window!

Mussels in the vicinity of Cape Falcon and nearby Arch Cape are probably of little importance. They are small at Arch Cape and difficult to collect at Cape Falcon where it is necessary to hike almost 2 miles to reach the beds at the tip of the cape.

At Cape Meares mussels are almost entirely lacking on the north side where the rocks are accessible. The remainder of the cape is inaccessible. There are mussels high on a few rocks on Short Beach (one mile south

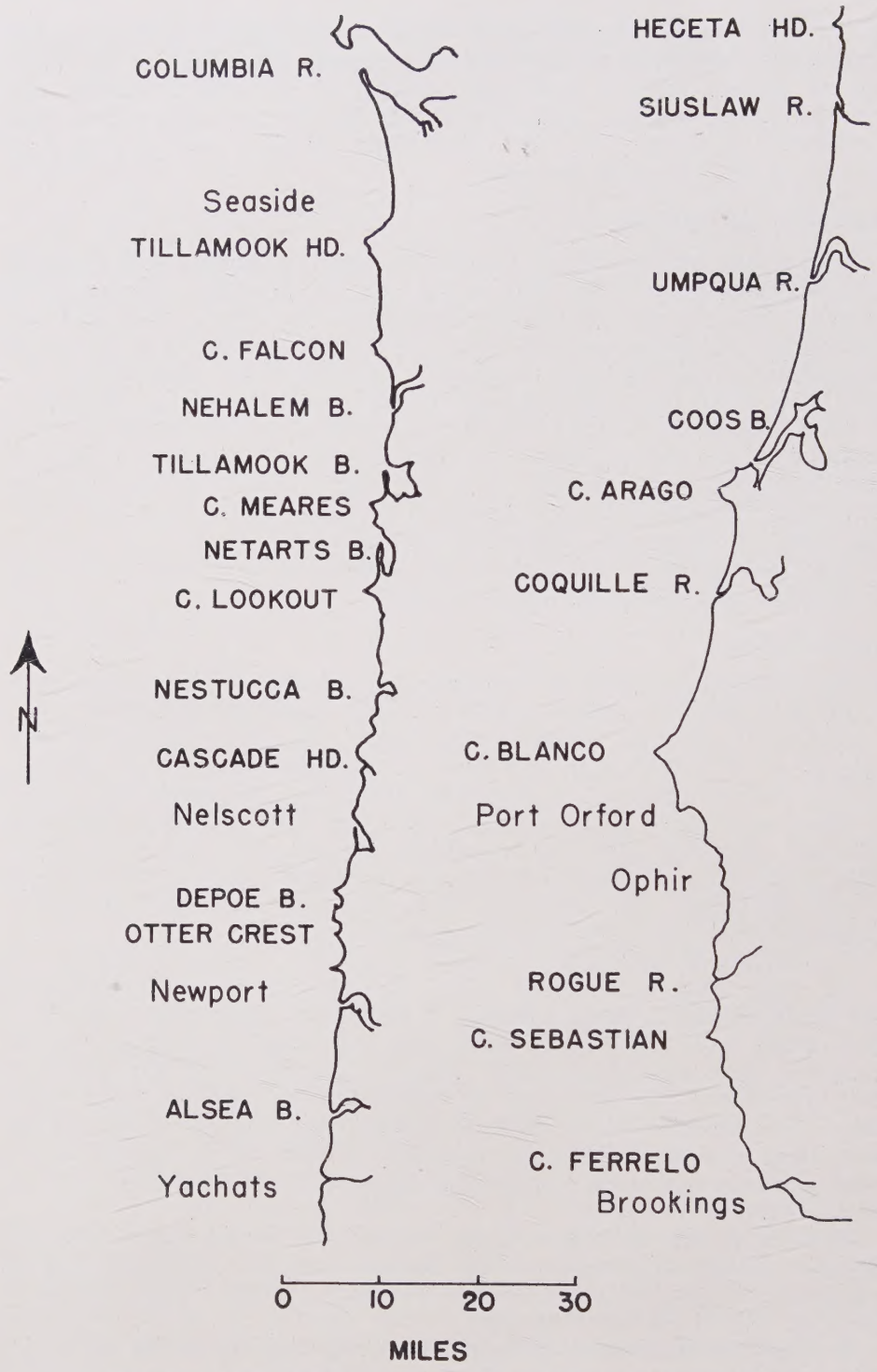

FIGURE 1. THE OREGON COASTLINE SHOWING LOCATION OF PRINCIPAL LANDMARKS.

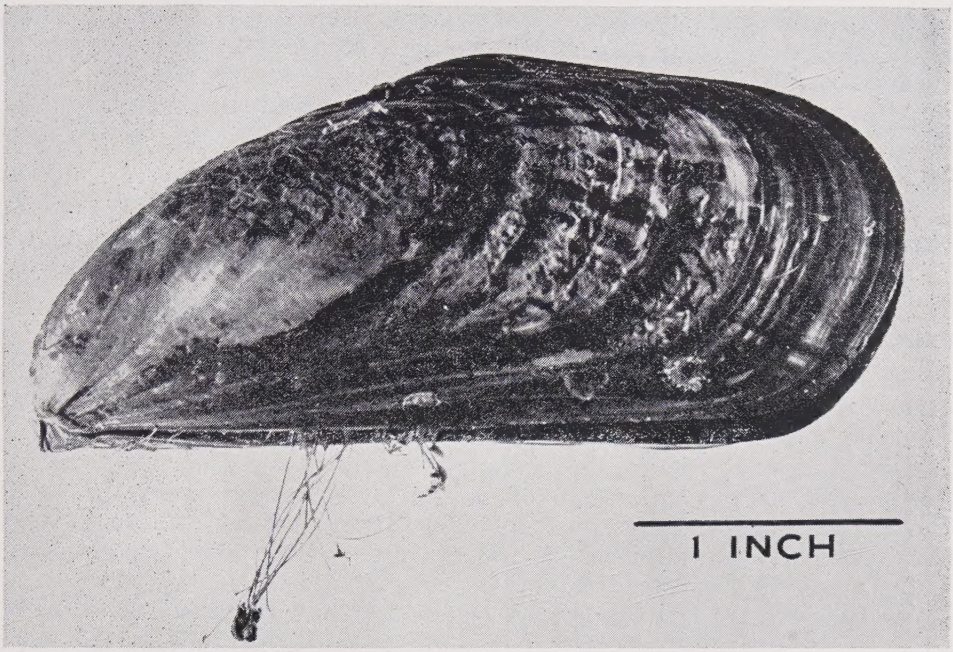

FIGURE 2. THE CALIFORNIA MUSSEL, *MYTILUS CALIFORNIANUS* CONRAD.

of Cape Meares) and at Maxwell Point (1¾ miles south of Cape Meares) but neither area is particularly important.

Cape Lookout is inaccessible with two exceptions. The outer end may be reached by hiking 5 miles, and the "marine gardens" near the base of the south side can be reached only by hiking by way of Camp Meriwether boy scout camp.

The mussels at Cascade Head are accessible only at the margins of the Head near the town of Neskowin and at Three Rox. Across the Salmon River from Three Rox there are mussels on some of the rocks near Camp Westwind (YWCA), but they are relatively inaccessible.

Mussels are found on the reefs near the towns of Nelscott and Oceanlake (2 miles north of Nelscott) where some are taken for food. Here they are relatively high on most of the rocks and project through and above the piddock beds.

The 7 miles between Lincoln Beach (3 miles north of Depoe Bay) and Otter Crest consists almost entirely of a rocky lava formation. There are mussels of moderate size and good abundance on most of the more exposed rocks in this area. They are inaccessible to the public in some areas because private property must be crossed to reach the shore. Mussels are accessible in the cove at Depoe Bay where it is possible to get to the rocks directly from Highway 101. They are also accessible at Boiler Bay, Pirate Cove, and Rocky Creek State Park, though at Boiler Bay it is necessary to cross private property in order to reach the mussel-bearing rocks. Just north of Otter Rock a trail leads to a shelf that extends along the shore to a point beneath Otter Crest. There are some mussels on these rocks but they are small and of little importance.

At Yaquina Head (between Newport and Otter Crest) there is a large rocky area on the south side which can be reached by trails leading from the turnaround at the lighthouse. This area is accessible and one of the important areas for mussels. Large mussels are present and some are quite accessible, though the larger ones can be obtained most easily at the lowest tides.

The reef off Newport (Nye Beach) contains only a limited number of small mussels.

At Seal Rocks, 8 miles south of Newport, there are a few large mussels, but most of these are on the seaward sides of the rocks and largely inaccessible.

At Yachats there are mussels on the rocks on both sides of Yachats River. At Yachats Rock State Park one can easily gather mussels from the rocks where they are large and numerous. On the opposite (south) side of the river at Yachats Beach State Park, mussels can also be gathered though they are not so large as on the north side of the river. South of Yachats there are numerous outcroppings of rock, all of which bear mussels. These rocks are accessible at low tide in most of the area from Yachats south to Cape Cove except the outer parts of Heceta Head just north of Cape Cove. There are reefs in the sandy beaches at many places along this area which are reported to bear mussels which are utilized by local residents. South of Cape Cove the rocky coast in the vicinity of Sea Lion Caves (1¼ miles south of Heceta Head) is inaccessible, and south of this for 43 miles the coastline consists of sandy beach.

In the region of Coos Bay there are mussel beds on most of the exposed rocks. One of the most extensive in the state is found at Mussel Reef (2 miles north of Cape Arago). Other beds are located at Squaw Island, Sunset Bay, Lighthouse Reef, and Cape Arago. These are all extensive and accessible with the possible exception of the ones on Squaw Island which require a low tide to reach and where there is some danger of becoming marooned by the incoming tide.

Between Cape Arago and Coquille River mussels are found at Agate Beach. Interviews with local residents indicate that the mussels are utilized as food in small quantities.

From the mouth of the Coquille River southward mussels occur in small beds. There are many such beds, most of which contain small mussels. The most notable beds are found at Coquille Point, Cape Blanco, The Heads (near Port Orford), Sisters Rocks, Hubbard Mound, Cape Sebastian, Cape Ferrelo, House Point, and Chetco Point. Coquille Point and Chetco Point are accessible, but the other areas are not.

Although the California mussel is to be found on almost all rocky areas along the Oregon coast, it is not widely utilized for food. A small commercial fishery for mussels existed during the years 1944 to 1946 near Seaside. The Indians from some of the coastal areas are reported to have used mussels for food, and the shell middens of the past are composed almost exclusively of fragments of mussel shells. These middens have been observed along most of the coast and are particularly evident at locations where erosion has taken place. Many mussels are used each

year for fish bait, and many more are torn from the rocks and discarded by fishermen searching for the polychaete worms which inhabit the mussel beds.

The smooth pea-pod borer, *B. californiensis*, was the only other mussel noted in this survey on the outer coast. While it was very abundant in certain localities, especially at Nelscott, its small size renders it undesirable for food. The specimens examined averaged 2 inches in shell length. It was also found at the entrance of Alsea Bay, Nye Beach (Newport), and at other scattered points along the coast.

The rough pea-pod borer, *B. falcata*, has been found near Coos Bay by students of the Oregon Institute of Marine Biology at Charleston but the exact location is unknown. Other mussels reported from Oregon by other workers were not observed during the 1953 survey.

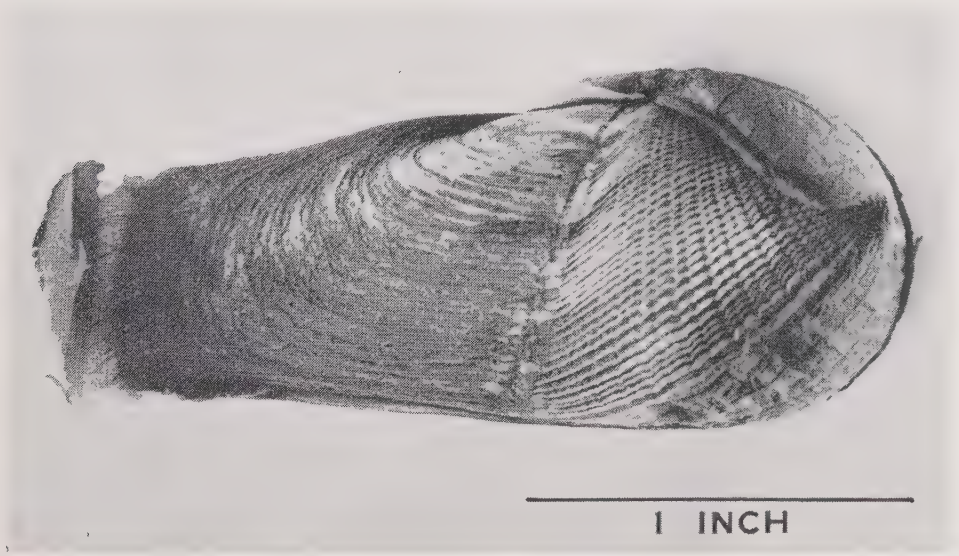

FIGURE 3. THE FLAP-TIPPED PIDDOCK, *PHOLADIDEA PENITA* CONRAD.

Piddock Surveys

P. penita, the flap-tipped piddock, is the only piddock that is commonly found in Oregon (Figure 3). Several other species are present but they are not economically important. The largest piddock collected during the survey was 3¼ inches in shell length, although the majority of mature specimens collected ranged from 1½ to 2½ inches. This piddock is found in nearly all of the rocky areas of the coast, but is abundant only where there is soft sedimentary rock. There are several reefs in the state which are important as piddock beds. These will be discussed in their geographical distribution from north to south.

The base of the cliff on the north side of Cape Meares has several layers of sandstone containing piddocks. These are in general, small, mature individuals averaging only 1½ inches in shell length.

The reefs off Oceanlake, Nelscott, and Delake are low and lie parallel

to the shoreline. They are accessible at low tide, but are not exploited extensively. At Nelscott Beach the reef is 1.0 mile long; at Oceanlake about 0.3 mile long; and at Delake about 0.1 mile long.

The reef off Nye Beach (Newport) has the most extensive piddock bed in the state. This reef is about 3 miles long and consists of low rocks lying parallel to the shoreline and covered only at high tide. The rocks represent the upper edges of sedimentary strata and are literally filled with piddocks, especially on the shoreward side. The smaller individuals bore their total length (including neck) beneath the surface of the rock and as they become older and larger they bore deeper into the rock so that the larger individuals are overlaid with a layer of smaller, immature individuals. These piddocks are usually taken with a pick or more easily with a large spike and a small sledge hammer. Piddocks obtained from Nye Beach are utilized primarily for food, but many are also used as bait for fishing in the tidepools of the reef.

On the south side of the mouth of Alsea Bay a small outcropping of rock at the margin of the channel contains many piddocks. However, the characteristic soft rock of the area splits (cleaves) poorly and often piddocks are damaged during digging operations.

Pockets of soft rock in the floor of some of the small coves at Yachats Rock State Park contain many piddocks. The rock here is harder than in the previously mentioned areas, but because of excellent cleaving qualities, it is possible to gather piddocks with little breakage. This area is small and probably not very important.

The rocks south of Yachats for several miles are reported to contain piddocks, but they are apparently taken only by a few local residents who use them for food.

At Fivemile Point, about 6 miles north of the mouth of the Coquille River, there is a large reef consisting of eight to ten lines of rock parallel to the shoreline and exposed only at low tide. The reef was found to contain many piddock holes, but few live individuals. The rock is hard in this area and digging is not very profitable. This is the southern most area in the state where piddocks are gathered.

In general it appears that piddock abundance is maximal at Nye Beach and declines to the north and south. There are practically none available in the harder rocks south of the Coquille River nor north of Cape Meares. Most of the piddocks that are taken are utilized for food, although some are used for bait by those who fish off the reefs. Piddocks seem to be localized in relatively small beds.

Because there is permanent destruction of suitable habitat each time piddocks are taken, they may be facing serious depletion within the intertidal zone. When the suitable rock has been chipped away by diggers, there will be few piddocks left in the intertidal zone. Furthermore, the smaller, younger piddocks which lie near the surface of the rock must be destroyed in order to collect the larger, mature individuals.

Z. pilsbryi, the rough piddock, has been reported from Sunset Bay (2 miles south of Coos Bay) and from Fossil Point in Coos Bay. It is also found in Yaquina and Netarts Bays and is probably present else-

where on the Oregon coast. This species is of little importance because of its relatively rare occurrence.

A small piddock, *P. parva,* was found embedded in the shell of a red abalone, *H. rufescens*, taken from the Brookings area (Figure 4). This record extends the previously known northern range from central California to Chetco Cove.

FIGURE 4. THE RED ABALONE, *HALIOTIS RUFESCENS* SWAINSON, AND THE SMALL PIDDOCK, *PHOLADIDEA PARVA* TRYON (CIRCLE INDICATES LOCATION OF EMBEDDED PIDDOCK).

Abalone Surveys

Shells of the red abalone, *H. rufescens*, which were reportedly taken from Chetco Cove on the south side of Cape Ferrelo and the cove between Cape Ferrelo and House Point, near Brookings, were examined and identified by the authors (Figure 4). Local residents reported this form was taken during offshore diving expeditions to the rocks off Whales Head Island (2½ miles north of Cape Ferrelo) and as far north as Nesika Beach near Ophir. No live abalone were found by the authors, although trips to the areas were made for this purpose. The extent of the fishery is presumably limited and the red abalone are not abundant. All abalone reportedly taken in the area have been large individuals, 10 to 11 inches in length. There have been no reports of small abalone in the Brookings area. The time of harvesting is said to be the first good low tide series in the spring.

Abalone are undoubtedly eaten by those fortunate enough to find them, and the shells used as ornaments. However, information gathered to date indicates they are present only in small numbers.

The small northern green abalone, *H. wallalensis,* occasionally found at Cape Blanco and Cape Arago, is not common. Specimens collected on the outer coast in the Coos Bay region by students of the Oregon Institute of Marine Biology at Charleston were examined and verified by the authors.

The black abalone, *H. cracherodii,* has been found in the vicinity of Coos Bay (Bonnot, 1948), but was not encountered during this survey.

Oregon is also included in the range of the Japanese abalone, *H. kamschatkana,* (Bonnot, 1948) but the authors have not seen any specimens nor heard of any collections of this species in Oregon waters.

Conclusions and Summary

1. The California mussel, *Mytilus californianus,* is the most abundant shellfish species found along the rocky outer coast of Oregon. It is present on virtually all of the rocky areas of the coast and appears to be most abundant in the Coos Bay region near Cape Arago. This species is utilized to a limited extent for food and fish bait.

2. The flap-tipped piddock, *Pholadidea penita,* is found in most of the rocky regions of the coast, but the areas of soft stone in which it is easily collected contain the greatest number of this delicious shellfish. It is most abundant in the reef at Nye Beach at Newport and is almost absent in the area south of the Coquille River and north of Cape Meares. Although this piddock is utilized for food and to a lesser extent for bait, it is not extensively exploited. Removal of this species from the intertidal rocks results in permanent destruction of the habitat.

3. The red abalone, *Haliotis rufescens,* is present only in the southern part of Oregon and in limited quantities. It cannot be considered an important species in Oregon. The few that are taken are utilized for food.

4. Other species of mussels, piddocks, and abalones are reported to occur along the Oregon coast, but are of little or no importance.

5. Since the authors found no published records of the occurrence in Oregon of *Haliotis rufescens,* it is believed that the known geographical range for this species should be extended from Point St. George in northern California to at least as far north as Chetco Cove near Brookings, Oregon.

6. Similarly, the known geographical range of the small piddock, *Pholadidea parva,* should be extended from central California to Chetco Cove.

Acknowledgments

The success of this survey was due largely to the cooperation extended the authors by local residents along the coast. To these people we wish to express our gratitude.

Messrs. Stanley N. Wilkes and Rae E. Baxter, temporary members of the shellfish staff during the summer of 1953, assisted the authors on a number of the field trips.

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RAZOR CLAMS TAKEN EIGHT MILES OFF OREGON COAST

Several razor clams (*Siliqua patula*) were received from Captain Frank Parker of the trawler *New Mexico* who reported they were taken in 30 fathoms (8 miles offshore) off the Columbia River on August 22, 1955. The distribution of razor clams offshore is not well known, but they are not believed to commonly inhabit such deep water. They are harvested in the intertidal zone. The clams were small size, averaging 83 mm. (3¼ inches). The periostracum was badly eroded, indicating an atypical habitat, possibly rocky bottom. A ratio of length to width was compared with that of clams taken from the beach, but no difference was found. The flesh was somewhat darker than the flesh of clams found on the beaches.

Robert J. Ayers

THE TRANSFER OF HATCHERY FISH TO ESTUARINE WATERS

JOHN T. GHARRETT①

Introduction

In 1948 and 1949 experiments were conducted on the Nehalem River to explore the possibilities of planting hatchery-reared chinook salmon *(Oncorhynchus tshawytscha)* and silver salmon *(O. kisutch)* fingerlings (0-age group—fish less than 1 year old) directly into the estuary of the river. It was felt that if such a procedure should be feasible, it might be of considerable advantage in hatchery management, providing that the homing tendencies of the fish would not be altered. The competition for food in the upper reaches of the streams, which occurs between naturally-reared fish and planted hatchery-reared fish, could be eliminated; and possibly the natural mortality which occurs during the downstream migration of the young salmon could be reduced. Also the cost of holding many 0-age group fish in hatchery rearing ponds until the following spring, as is usually the practice, might be eliminated.

These experiments were carried out incidentally to the other work of the staff of the coastal rivers investigations, and consequently did not receive the detailed attention that would have been desirable. However, the results do indicate possibilities which appear to merit further investigation.

Equipment and Methods

In the original experiment the young salmon were placed in live boxes on the lower reaches of the river above tidewater, and were moved by stages, during a period of about 2 weeks, down into the estuary in order that the fish might become acclimatized to the temperatures and salinities of the estuarine water. The live boxes were moved by towing them and in so doing the force of the water washed many of the small fish against the live box screens causing considerable mortality. Thereafter, live boxes were stationed in the estuary of the river at the towns of Wheeler, in 1948, and Brighton, in 1948 and 1949, about 4 miles and 1 mile, respectively, above the mouth of the Nehalem River. From time to time hatchery fish were introduced directly into these live boxes or transferred from one location to the other. Experiments 1 (Table 1) consist of fish surviving from the original experiments, and those with an "X" suffix indicate a continuation of experiments after the fish were transferred to a new location.

The live boxes were usually attended every second or third day, but at times they were left unattended for longer periods. During these visits, the screens covering the boxes were cleaned, the fish were fed standard hatchery food, and temperature and hydrometer readings were taken.

Nehalem Estuary Temperatures and Salinities

The temperature and salinity of the Nehalem estuary fluctuates considerably throughout the day and season. The river flow and tidal cycles affect the salinity, while these factors plus atmospheric conditions affect the temperature. In these experiments, the specific gravity of the water was used as a measure of the salinity. This varied from 1.000 (fresh-

① Formerly Aquatic Biologist with the Oregon Fish Commission; now Research Coordinator with the Pacific Marine Fisheries Commission.

water) to 1.030. The specific gravity is also related to the water temperature, but the data of these experiments are not precise enough to warrant a correction for water temperature. On several occasions, half-hourly or hourly temperature and specific gravity readings were taken for a period of several hours. Examples of the fluctuations of temperature and specific gravity during such periods, as shown in Figure 1, demonstrate the changes to which the fish held in the live boxes were subjected.

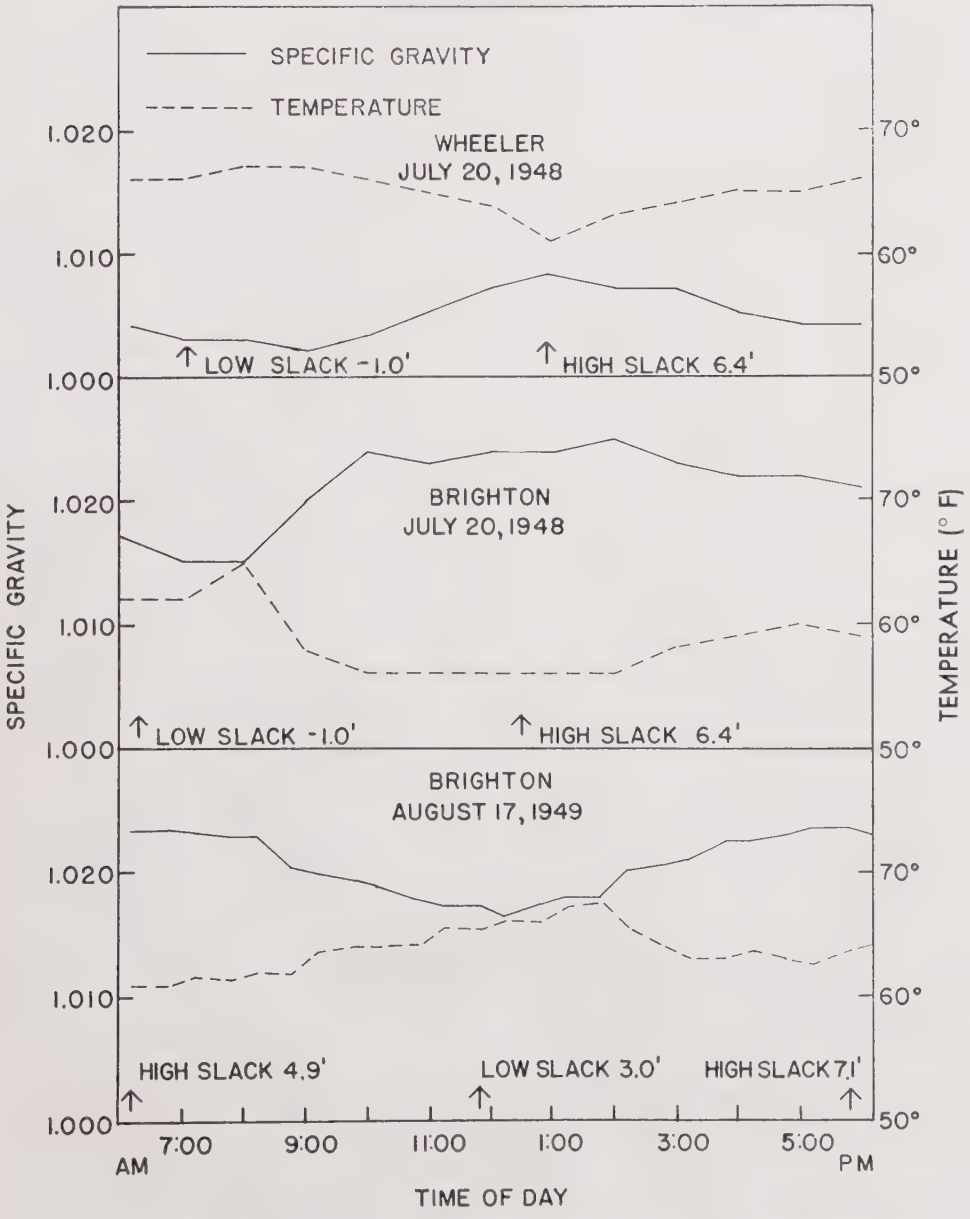

FIGURE 1. SPECIFIC GRAVITY AND TEMPERATURE READINGS AT WHEELER AND BRIGHTON, JULY 20, 1948, AND AT BRIGHTON, AUGUST 17, 1949.

Discussion

The location and duration of each experiment, together with numbers of fish involved, percentage survival, mean length, and size range are included in Table 1. Cumulative mortalities by 10-day periods, to 40 days, are shown in Figure 2. Some experiments were terminated before this length of time, i.e., 40 days, while others exceeded it. However, the greatest mortalities usually occurred within 10 days after introduction of the fish into the live boxes. Mortalities thereafter were generally light, probably not much greater than would have occurred had the fish been held in hatchery ponds.

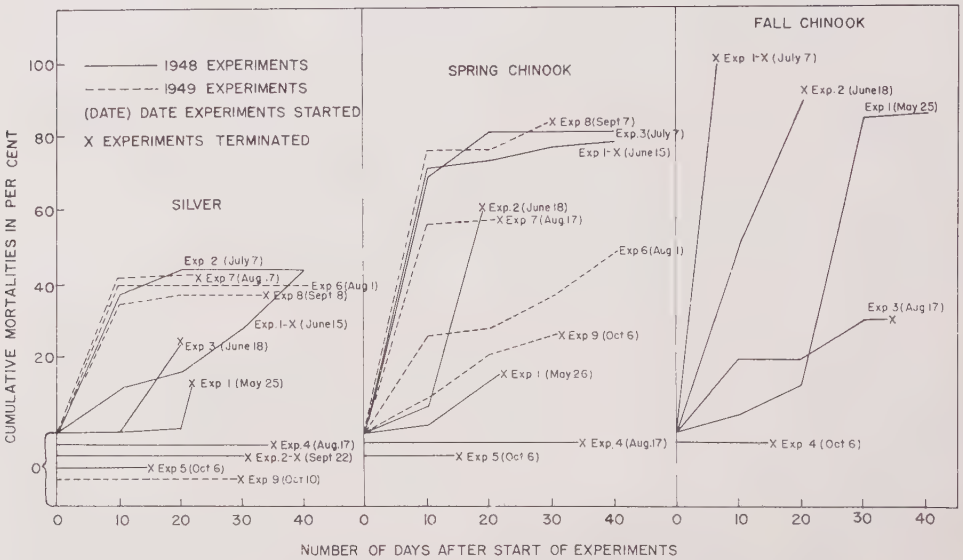
1948 EXPERIMENTS
1949 EXPERIMENTS
(DATE) DATE EXPERIMENTS STARTED
X EXPERIMENTS TERMINATED
SILVER
SPRING CHINOOK
FALL CHINOOK
CUMULATIVE MORTALITIES IN PER CENT
NUMBER OF DAYS AFTER START OF EXPERIMENTS
Exp. 2 (July 7)
X Exp 7 (Aug. 7)
Exp 6 (Aug 1)
X Exp 8 (Sept 8)
Exp. 1-X (June 15)
X Exp 3 (June 18)
X Exp 1 (May 25)
X Exp 4 (Aug. 17)
X Exp. 2-X (Sept 22)
X Exp 5 (Oct 6)
X Exp 9 (Oct 10)
X Exp 8 (Sept 7)
Exp. 3 (July 7)
Exp 1-X (June 15)
X Exp. 2 (June 18)
X Exp 7 (Aug 17)
Exp 6 (Aug 1)
X Exp 9 (Oct 6)
X Exp 1 (May 26)
X Exp. 4 (Aug. 17)
X Exp 5 (Oct 6)
X Exp 1-X (July 7)
X Exp. 2 (June 18)
Exp 1 (May 25)
Exp 3 (Aug 17)
X
X Exp 4 (Oct 6)

FIGURE 2. CUMULATIVE MORTALITIES BY TEN-DAY PERIODS AFTER PLACING FISH IN LIVE BOXES.

The results of the various experiments were somewhat inconsistent, and for this no explanation is offered. However, some of the experiments (Numbers 2-X, 4, 5, and 9) suggest that 0-age group hatchery-reared silver salmon can, in the fall of the year, be successfully introduced into the saline waters of the Nehalem River estuary without suffering serious mortalities. There are some indications that 0-age group hatchery-reared chinook, both of the spring run (Experiments 4 and 5) and fall run (Experiment 4) might likewise be successfully introduced. The chances of success seem to increase as the season progresses, but it cannot be concluded from the data whether this is a function of size and/or age of the fish, water conditions, or a combination of these.

It is realized that by holding these fish in a fixed location, they were handicapped by not being able to seek preferred conditions and possibly a more consistent supply of food. Had they not been confined, perhaps they would have been better able to withstand the transfer from the hatchery to the estuary.

TABLE 1. DATA ON TRANSFER EXPERIMENTS

EXP. NO.	LOCATION	SOURCE OF FISH	DURATION OF EXPERIMENT			NO. OF FISH			MEAN LENGTH (mm.)		SIZE RANGE (mm.)	
			Begin	End	Nos. of Days	Begin	End	Per Cent Surviving	Begin	End	Begin	End
			SILVER SALMON—1948									
1	Wheeler	Upriver Live Box①	May 25	June 15	21	283	250	88	53.1	NR①	44–62	NR
1–X	Brighton	Wheeler	June 15	Sept. 28	105	250	78	31	NR	83.2	NR	53–112
2	Wheeler	Trask Hatchery	July 7	Sept. 22	77	25	11	44	58.6	92.4	55–65	88–97
2–X	Brighton	Wheeler Live Box	Sept. 22	Oct. 20	28	11	11	100	92.4	97.8	88–97	90–108
3	Brighton	Trask Hatchery	June 18	July 7	19	25	19	76	55.7	60.4	50–63	55–65
4	Brighton	Trask Hatchery	Aug. 17	Sept. 20	34	10	10	100	73.6	80.9	65–82	76–88
5	Brighton	Trask Hatchery	Oct. 6	Oct. 20	14	10	10	100	83.2	83.7	70–103	73–101
			SILVER SALMON—1949									
6	Brighton	Foley Creek Hatchery	Aug. 1	Oct. 10	70	100	48	48	81.7	85.4	59–102	68–108
7	Brighton	Trask Hatchery	Aug. 17	Sept. 8	22	100	57	57	70.3	72.0	58–91	60–83
8	Brighton	Foley Creek Hatchery	Sept. 8	Oct. 10	32	100	61	61	92.8	92.9	83–104	82–109
9	Brighton	Foley Creek Hatchery	Oct. 10	Nov. 7	28	100	100	100	101.6	102.2	86–123	88–123
			SPRING CHINOOK SALMON—1948									
1	Wheeler	Upriver Live Box	May 26	June 15	20	113	96	85	61.9	NR	51–74	NR
1–X	Brighton	Wheeler Live Box	June 15	Sept. 28	105	91	20	22	NR	104.7	NR	83–116
2	Brighton	Trask Hatchery	June 18	July 7	19	20	8	40	75.7	80.6	63–84	68–90
3	Wheeler	Trask Hatchery	July 7	Sept. 22	77	16	2	13	71.2	114.5	55–83	107–122
4	Brighton	Trask Hatchery	Aug. 17	Sept. 20	34	10	10	100	105.8	115.5	94–112	106–126
5	Brighton	Trask Hatchery	Oct. 6	Oct. 20	14	10	10	100	116.3	116.5	100–132	100–133
			SPRING CHINOOK SALMON—1949									
6	Brighton	Trask Hatchery	Aug. 1	Oct. 10	70	74	22	30	87.6	103.0	65–110	66–126
7	Brighton	Trask Hatchery	Aug. 17	Sept. 7	21	75	32	43	100.3	103.0	79–122	79–130
8	Brighton	Trask Hatchery	Sept. 7	Oct. 6	29	47	8	17	118.8	121.8	80–141	115–130
9	Brighton	Trask Hatchery	Oct. 6	Nov. 7	32	58	37	64	115.9	116.1	77–154	87–145
			FALL CHINOOK SALMON—1948									
1	Wheeler	Upriver Live Box	May 25	July 7	43	286	16	6	52.9	63.1	39–62	52–79
1–X	Brighton	Wheeler Live Box	July 7	July 13	6	16	0	0	63.1	.....	52–79	.....
2	Brighton	Trask Hatchery	June 18	July 7	19	30	3	10	59.1	66.6	55–63	63–68
3	Brighton	Trask Hatchery	Aug. 17	Sept. 20	34	10	7	70	76.1	79.4	66–89	64–101
4	Brighton	Trask Hatchery	Oct. 6	Oct. 20	14	10	10	100	90.4	90.1	82–107	82–107

① Not recorded.

Acknowledgments

The facilities provided by Messrs. Forrest M. Johnson, Ernest N. Snider, and Louis E. W. Ludtke, for moorage of the live boxes used in these experiments are gratefully acknowledged. Various members of the coastal salmon investigation staff contributed to this work. These include John I. Hodges, Kenneth A. Henry, Robert L. Rulifson, Robert I. Clutter, Albert C. Jones, and Harry Schachter.

ADULT STEELHEAD RAPID MIGRATORS

Two tagged steelhead have been recovered in the Columbia River gill-net fishery, after being tagged and released in the Snake River several hundred miles above the places of recovery.

The first of these was a 23-inch steelhead which was tagged and released in good condition on April 27, 1954, and which was caught by Mr. Chris Simonson of Astoria 25 days later off the Point Adams Packing Company plant at Hammond, Oregon. When recovered, the spent steelhead was thin with frayed fins and in very poor condition.

The second was a 31-inch steelhead which was tagged May 20, 1954, and although it had old gill-net marks at the time of tagging, was also released in good condition. It was spent and in poor condition when caught by Mr. N. H. Forsberg of Ridgefield, Washington, 26 days later near Multnomah Falls in the Columbia River. Mr. Forsberg released the steelhead alive with the tag intact after recording the tag number.

At the time of tagging, both of these steelhead apparently were sexually mature and enroute to their spawning grounds. The recoveries are all the more remarkable since each of these two fish apparently spawned and migrated 350 to 450 miles downstream over McNary and Bonneville Dams in the short space of less than a month.

Theodore R. Merrell

BURBOT CAUGHT IN COLUMBIA RIVER

Burbot or ling (*Lota maculosa*) are not common to the lower Columbia River. On May 16, 1954, a 9¼ pound female was captured in a commercial gill net near Bridal Veil, Oregon, by Ray Holtgrieve and was forwarded to the Oregon Fish Commission for identification and examination. The presence of a partially digested scrap fish in the stomach suggests that these fish deserve their reputation as being predaceous.

Harry L. Rietze

SHAD SPAWNING SEASON LENGTHY

Shad spawning activities in the Columbia River system during 1953 were observed to span a period of more than four months. On May 11, 1953, several running ripe shad were observed in the Willamette Slough. On September 18, 1953, a ripe male and female shad were observed among salmon landings from near the mouth of the Big White Salmon River, a distance of about 80 miles up the Columbia from the mouth of Willamette Slough.

Harry L. Rietze

ESCAPEMENT OF SPRING CHINOOK SALMON AND STEELHEAD OVER WILLAMETTE FALLS IN 1953

EARL F. PULFORD

Introduction

Each spring since 1946 a counting station has been operated at Willamette Falls in order to enumerate the spring chinook salmon *(Oncorhynchus tshawytscha)* run past this site.

The major spawning and rearing areas utilized by spring chinook salmon in the Willamette River are above Willamette Falls, which is located at Oregon City, Oregon, about 20 miles above the confluence of the Willamette and Columbia Rivers (Figure 1). The only tributary which spring chinook enter below the falls is the Clackamas River. This stream at present has only a relatively small run, although formerly it was a good producer of spring chinook.

Before reaching Willamette Falls the salmon contribute to the ocean troll, the Columbia River gill-net, and the lower Willamette River sport fisheries. In addition, during the past three years there has been a significant sport catch of salmon in the tributary streams above Willamette Falls. The bulk of the escapement over the falls, however, can be considered to be the spawning population. No data are presently available concerning the intensity of the sport fishery above the falls or the summer mortality prior to spawning, except in the immediate vicinity of such large dams as Detroit and Lookout Point, where, during various stages of construction, severe losses of several thousand fish have occurred in recent years (Figure 1).

By combining the Willamette Falls fishway count, the lower Willamette sport catch, and the Clackamas River sport catch and escapement, the annual run of spring chinook salmon into the Willamette River can be estimated with reasonable accuracy.

Procedure

The same procedure was used this season in operating the counting station as has been used in previous years of study. Local residents were employed as counters. The daily counting period of 13 hours was divided into two shifts. The first shift extended from 7:00 a.m. until 1:30 p.m., while the second shift was from 1:30 p.m. through 8:00 p.m.

The counting periods were further divided into 25-minute units commencing on the hour and half-hour, followed by 5-minute rest periods during which counters recorded data and rested their eyes. Corrections for these 5-minute periods were made by assuming the same rate of passage as observed during the previous 25 minutes of counting.

Correction Factor for Night Migrations

Salmon continue to move through the fishway after the daily counting period ends. It is not practical to man the counting station throughout the hours of darkness, so a correction is made for the migration at night, when no counting is done.

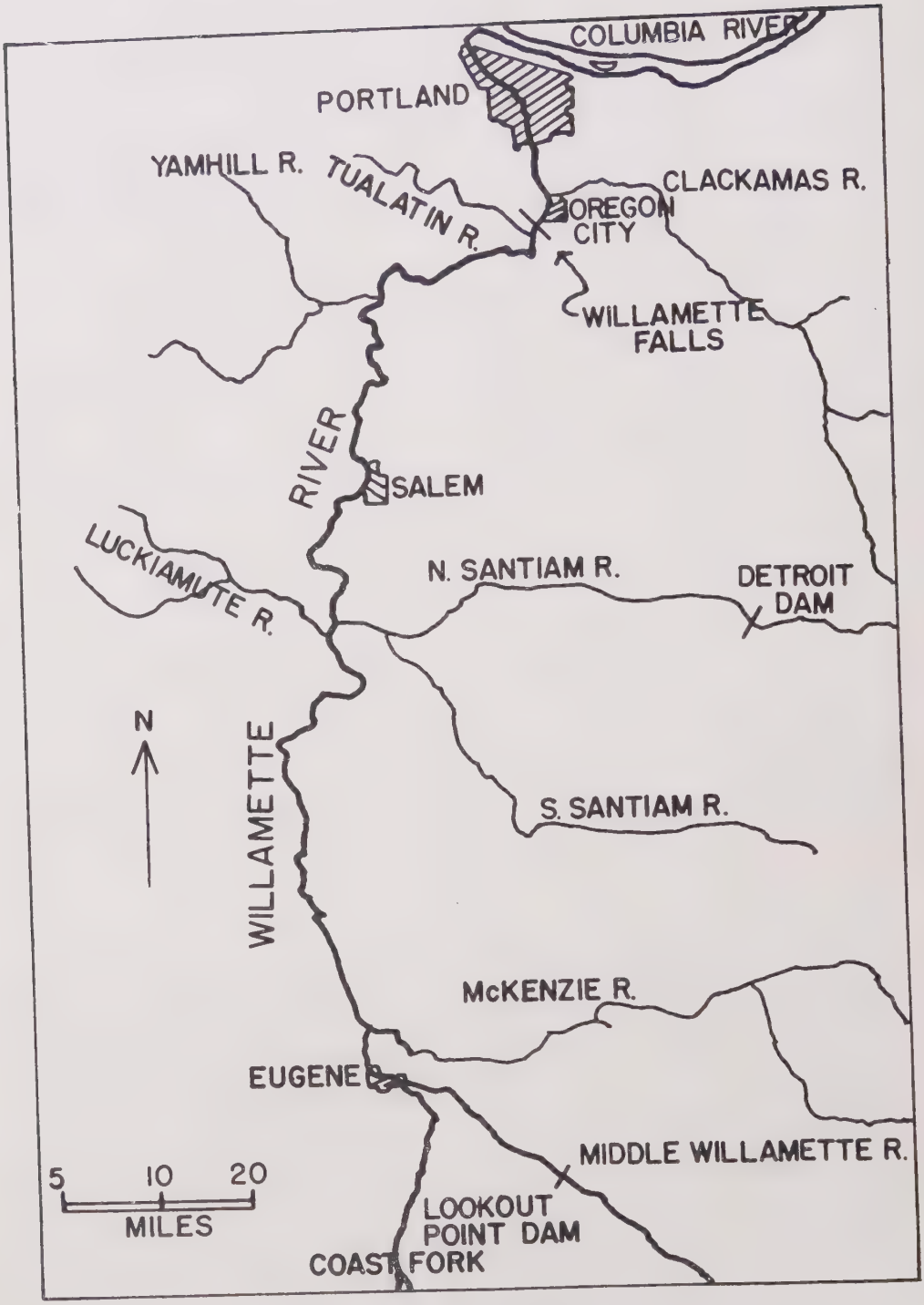

FIGURE 1. WILLAMETTE RIVER SYSTEM.

In previous years, studies of salmon migration at night at Willamette Falls indicated that the best correlation existed between the noon to 8:00 p.m. count and the night movement following this period (Johnson, 1948). It appeared that the bulk of the night migrants were salmon that had entered the ladder during the afternoon hours, and that relatively few had entered the ladder during the hours of darkness. Observations made shortly before daylight showed the fishway to be nearly empty of fish, but as light increased, fish again entered the ladder.

The numbers of salmon migrating at night vary considerably. These variations may result from several factors which appear to influence the rate of migration within the fishway during daylight and darkness. Examples of such variables are fluctuating water flows within the ladder (caused by varying river flows or change in use of water at the industrial plants in Oregon City), weather conditions, and water temperatures. Since these variables are present throughout the migration period, the average of all data collected has been used in arriving at a correction factor for estimating the night migrations (Table 1).

TABLE 1. **CHINOOK SALMON COUNTS AT WILLAMETTE FALLS USED IN DERIVATION OF CORRECTION FACTOR FOR NIGHT MIGRATION IN 1953**

Date	*Afternoon Count (AC) (12 m.—8 p.m.)*	*Night Count (NC) (8 p.m.—7 a.m.)*	*Night Migration Factor (NC/AC) (Per Cent)*
May 8-9, 1947	689	290	42.1
May 11-12, 1947	1,320	606	45.9
May 15-16, 1947	561	150	26.7
May 26-27, 1947	265	98	37.0
June 2-3, 1948	963	270	28.0
June 3-4, 1948	270	60	22.2
May 25-26, 1949	789	232	29.4
May 21-22, 1951	864	271	31.4
May 18-19, 1953	1,087	227	20.9
June 3-4, 1953	1,459	462	31.7
June 4-5, 1953	1,763	453	25.7
Total	10,030	3,119	31.1

Three 24-hour period counts were made in 1953 on the following dates: May 18-19, June 3-4, and June 4-5. The 24-hour migration pattern as determined from these three counts is shown in Figure 2. For all years of record (1947, 1948, 1949, 1951, and 1953) the average night migration was found to be 31.1 per cent of the afternoon counts. This factor has been used to estimate the night migration in 1953. The night migration factor changes slightly from year to year as more 24-hour counts are obtained and included in the computations.

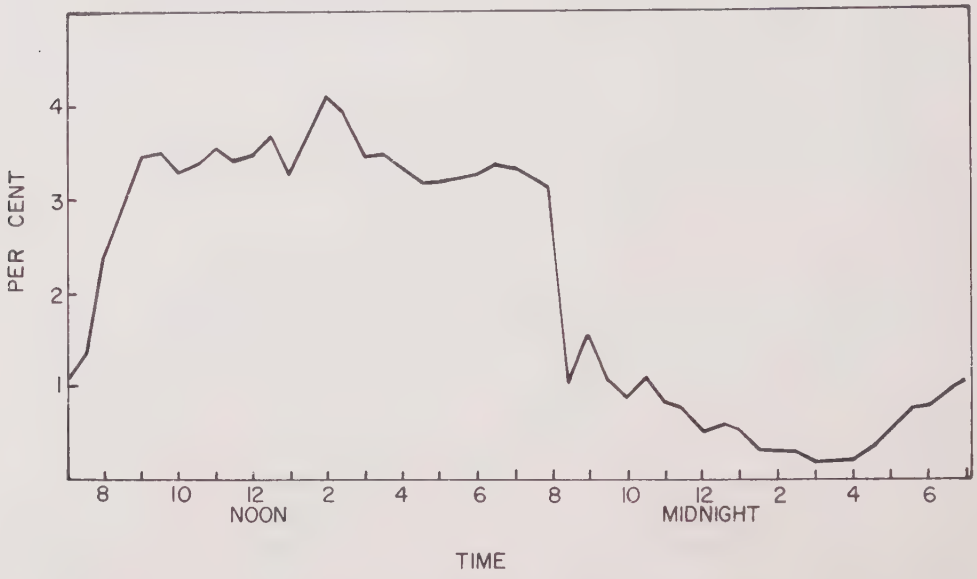

FIGURE 2. MIGRATION OF SPRING CHINOOK SALMON THROUGH WILLAMETTE FALLS FISHWAY IN 1953 DURING A 24-HOUR PERIOD.
(Average of Three 24-Hour Counts, Not Including Jacks)

Passage During Partial Count Periods

In order to estimate the daily migrations during those days when only partial counts were obtained, it was necessary to determine the half-hourly frequency of fish passage. Consequently, the adult (salmon over 20 inches in length) rate of migration through the day, expressed as a percentage of the 13 hour counting period, was plotted (Table 2 and Figure 3). Actual counts for 31 days, which included 38,962 salmon, were used in plotting the half-hourly frequency of migration. The 24-hour pattern of migration, as shown in Figures 2 and 3, is of considerable interest.

Between 7:00 and 8:00 a.m. (Figure 3) migration increased rapidly and after that the increase was only gradual until about 2:00 p.m. The afternoon migration leveled off and remained relatively constant until the end of the counting period.

TABLE 2. **SUMMARY OF MIGRATION OF SPRING CHINOOK SALMON, EXCLUDING JACKS, THROUGH WILLAMETTE FALLS FISHWAY IN 1953 BY 25-MINUTE PERIODS**

Time of Day	*Number of Fish*	*Per Cent of Total*	*Time of Day*	*Number of Fish*	*Per Cent of Total*
7:00– 7:25 a.m.	680	1.7	1:30–1:55 p.m.	1,678	4.3
7:30– 7:55	1,129	2.9	2:00–2:25	1,639	4.2
8:00– 8:25	1,157	3.0	2:30–2:55	1,551	4.0
8:30– 8:55	1,290	3.3	3:00–3:25	1,549	4.0
9:00– 9:25	1,354	3.5	3:30–3:55	1,633	4.2
9:30– 9:55	1,400	3.6	4:00–4:25	1,523	3.9
10:00–10:25	1,454	3.7	4:30–4:55	1,587	4.1
10:30–10:55	1,536	3.9	5:00–5:25	1,639	4.2
11:00–11:25	1,554	4.0	5:30–5:55	1,659	4.3
11:30–11:55	1,608	4.1	6:00–6:25	1,629	4.2
12:00–12:25 p.m.	1,588	4.1	6:30–6:55	1,643	4.2
12:30–12:55	1,608	4.1	7:00–7:25	1,575	4.0
1:00– 1:25	1,652	4.2	7:30–7:55	1,647	4.2
			Total	38,962	99.9

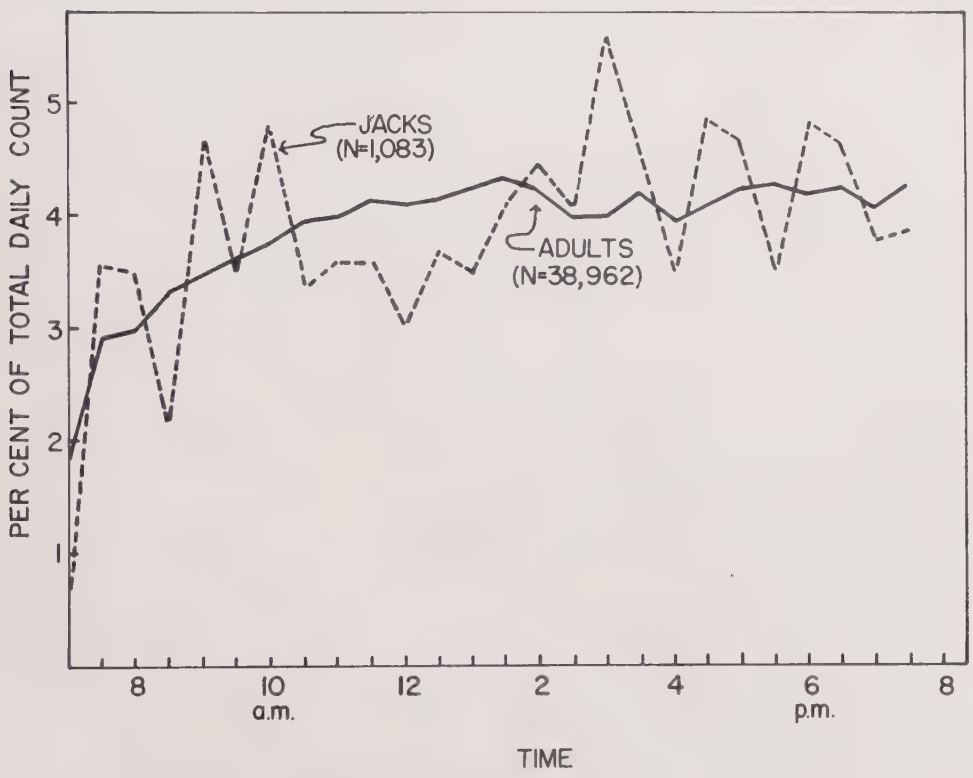

FIGURE 3. MIGRATION BY HALF HOUR PERIODS OF SPRING CHINOOK SALMON OVER WILLAMETTE FALLS IN 1953 AS A PERCENTAGE OF THE TOTAL DAILY 7:00 A. M. TO 8:00 P. M. COUNT.

With the approach of darkness at about 8:00 p.m., migration diminished sharply, reaching an extreme low point between 2:00 and 4:00 a.m. (Figure 2). Starting at daylight at about 4:00 a.m., migration again picked up, gradually increasing until 7:00 a.m.

This daily trend of migration was considerably different from that observed in 1947 (Johnson, 1948). He found a single distinct peak occurring between 3:00 and 8:00 p.m., in contrast to the relatively broad peak between about 9:00 a.m. and 7:00 p.m. No reason for this difference is apparent.

The migration of 1,038 jacks (precocious salmon, approximately 20 inches or less in length) was also calculated as a percentage of the total count by half-hour periods (Figure 3). There were smaller numbers of jacks involved and greater variations, but there were no sharply contrasting trends between the jack and adult chinook salmon daily movements.

Magnitude of the 1953 Escapement Over Willamette Falls

By correcting for 5-minute rest periods, night migrations, and days when only partial or no counts were made, the spring chinook salmon escapement through the fishway in 1953 was calculated to have been 72,300 adults and 4,100 jacks.

The counting station was operated for a period of 72 days from April 17 through June 30. During this time the number of salmon actually counted totaled 41,842 adults and 1,797 jacks. Corrections for the 5-minute rest periods increased these totals to 50,200 adults and 2,200 jacks. The remainder of the total (34 per cent) is made up of the calculated night migration and the estimated escapement during periods when the station was not in operation. The daily migration of spring chinook salmon in 1953 is depicted in Figure 4.

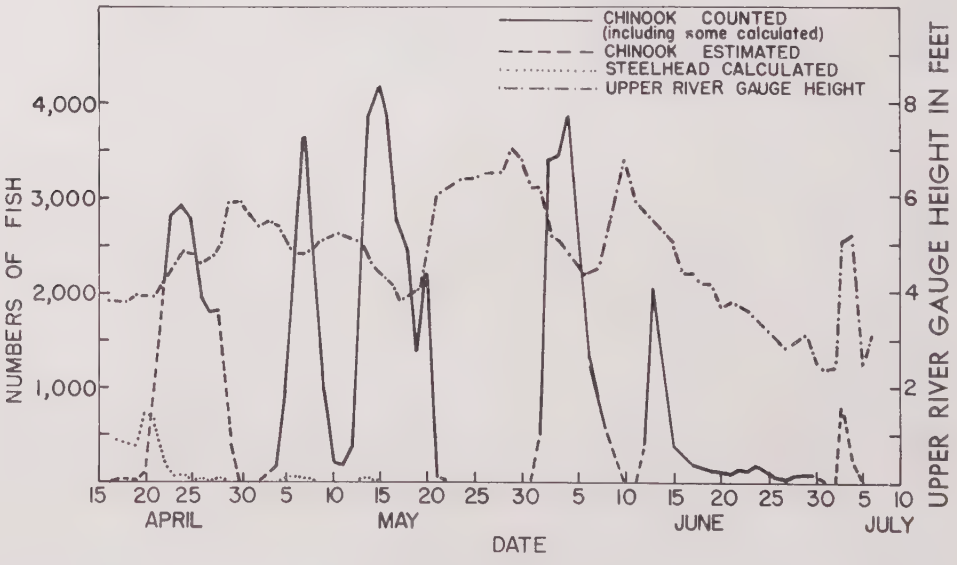

FIGURE 4. DAILY MIGRATION OF CHINOOK SALMON AND STEELHEAD OVER WILLAMETTE FALLS IN 1953.

Steelhead Migration

During the first portion of the counting season, steelhead were also moving through the ladder (Figure 4). The counters recorded 1,013 steelhead, which was increased to 1,216 fish after the rest period correction had been included. This figure is considerably under the 1952 count of 2,868 steelhead calculated to have ascended the fishway. However, this is not a reliable indication of the comparative sizes of the two runs, since in 1953 the conditions for fish passage were excellent for at least two weeks before the salmon counts were begun, and a heavy migration of steelhead was observed to have occurred during this time. In 1952 the movement of steelhead was delayed by high water and very likely a large portion of the run was counted. Sufficient data on the steelhead runs are not available to estimate the escapements.

Discussion of the Steelhead and Spring Chinook Salmon Escapements

In 1953 the fishway was passable through much of February, and it is believed that the bulk of the steelhead moved through during this period. Due to high flows the ladder probably became impassable about the first of March and remained so until the last week of March. With a drop in the river level, the ladder began to pass fish during the last week in March and continued to be passable during the first two weeks of April. During this time the steelhead movement through the fishway was very good, as indicated by observations made during several visits to the ladder prior to the initiation of systematic counting.

The first spring chinooks were observed in the ladder during the afternoon of April 17 when the counting began. On May 21 the river rose to such a stage that the fishway probably became impassable, as indicated by the absence of migration (Figure 4). This condition existed until the first of June. The river again rose on June 9, causing the fishway to become relatively impassable for 3 days until June 12. By June 19 salmon migration had fallen off so greatly that it was decided to continue only the afternoon count; the morning migration was calculated on a percentage basis (Table 2).

There were several major peaks of migration in 1953, the first occurring on April 25. Two peaks occurred in each of the months of May and June on the following dates: May 6 to 8, May 13 to 20, June 2 to 5, and June 14 (Figure 4). The large fluctuations in the salmon movements seem to be due to variations in the river levels at the falls. Sudden rises of the river brought about definite decreases or even cessations in movements as shown in Figure 4. River levels fluctuated more than usual during the 1953 season and caused a more extended period of migration than has been usual in recent years.

The small peak on July 4 was caused by the industrial mills at Willamette Falls ceasing operations for 24 hours. During low flow periods a major portion of the river flow is diverted at the falls to run the power turbines and hydraulic grinders at several industrial plants in Oregon City and West Linn. The various outlets of water from these plants form attractions that lead salmon into blind channels. The July 4 closure of the mills eliminated the attractions into blind channels, and the salmon

then were able to locate the ladder entrance. An observer was placed on duty at the fishway and estimated that approximately 1,000 salmon passed over the falls on July 4 and the day following.

Each year it has been noted that a sudden increase in the proportion of jack salmon in the counts seemed to indicate that the bulk of the chinook migration was over. Such was also the case in 1953. Figure 5 shows jack salmon as a percentage of the total daily salmon migration for each day of the season and total counts (including adults and jacks). During the prolonged period of heavy migrations, the actual number of jacks as well as the percentage, was quite low, but immediately following the last days of heavy migration there was a sudden increase in numbers in migrating jacks.

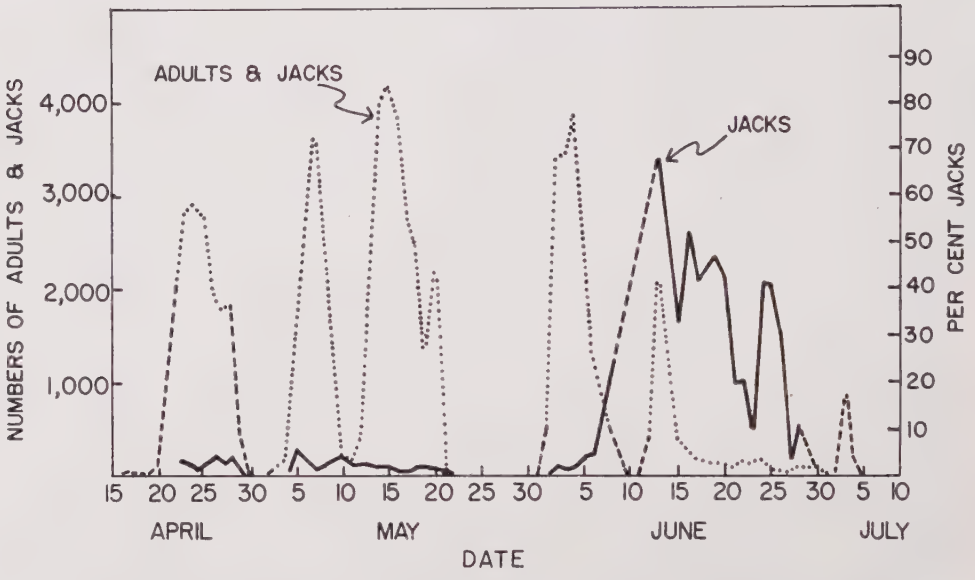

FIGURE 5. DAILY MIGRATION OF JACKS OVER WILLAMETTE FALLS IN 1953 AS A PERCENTAGE OF TOTAL SALMON COUNTS, AND TOTAL SALMON COUNTS.

The 1953 season was the third in which a comparison could be made between the parent and progeny runs. The 1946-1951 parent-progeny years were the first available for comparison. Only 34,300 fish passed over the falls in 1951 compared with 53,000 in the parent brood year of 1946, or a progeny escapement over the fishway only 65 per cent as large as the parent migration. However, considering the total returns to the Willamette River, including the sport catch and the Clackamas River escapement, the progeny run of 49,600 was 72 per cent as large as the parent run of 68,600[1]. This was an indication of a decline that had been evident during the previous decade, although no precise estimates of escapement were available prior to 1946.

The 1947-1952 parent-progeny comparison is more favorable. The 1947 escapement was 47,000 fish, compared with 52,200 in 1952. This indicates

[1] For methods of estimating Willamette River sport catch, refer to Mattson and Dimick, 1952.

an increase of 11 per cent over the parent run. Comparing the total Willamette River runs, including the sport catch and the Clackamas River escapement, the 1947 total of 61,000 was somewhat less than the 67,500 which returned in 1952, indicating a similar increase of approximately 11 per cent. This was the first indication that the downward trend of the Williamette River salmon runs may have been arrested.

The 1948-1953 comparison of parent-progeny runs appears to be even more encouraging. The 1948 falls escapement was 30,000 fish while in 1953 it was 76,400. This is an increase of 155 per cent over the parent run. Comparison of the total Willamette runs of 1948 and 1953 (40,100 and 96,800, respectively) indicates an increase of 141 per cent (Table 3).

TABLE 3. **ANNUAL WILLAMETTE FALLS FISHWAY COUNT, LOWER WILLAMETTE RIVER SPORT FISHERY CATCH, CLACKAMAS RIVER ESCAPEMENT, AND TOTAL WILLAMETTE RUN, 1946-53**

Year	*Willamette Falls Fishway Count (Calculated)*	*Lower Willamette Sport Fishery (Calculated)*	*Clackamas River Escapement (Estimated)*	*Total Run*	*Sport Catch as Per Cent of Run*
1946	53,000	12,600	3,000	68,600	18
1947	47,000	12,000	2,000	61,000	20
1948	30,000	8,300	1,800	40,100	21
1949	27,000	9,100	1,750	37,850	24
1950	14,500	8,800	1,500	24,800	35
1951	34,300	13,300	2,000	49,600	27
1952	52,200	12,500	2,800	67,500	19
1953	76,400	16,400	4,000	96,800	17

The sport fishery has had a significant effect on the escapement. For the period 1946 through 1953 the take has varied between 17 and 35 per cent of the run entering the Willamette. Because of this fluctuating catch it is of interest to make a further comparison of the escapement over the falls with the returning run to the river for the three cycles for which a comparison is possible (1946-51, 1947-52, and 1948-53). For each fish counted over the falls, there returned to the Willamette River five years later 0.9, 1.4, and 3.2 fish, respectively.

It should be pointed out that in all of the above comparisons of parent-progeny runs, the small annual Clackamas River escapement and contribution to the lower Willamette River sport fishery have been included in the total run figures, but not in falls escapement figures. This treatment probably does not significantly affect the comparisons.

Therefore the overall picture indicates a favorable trend. The cyclic returns comparing the total runs entering the Willamette, the escapements over the falls, and the escapement with the returning run to the river all indicate increasing production.

Summary

1. The period of major migration of spring chinook salmon over Willamette Falls in 1953 extended from April 15 to July 5, with 4 major peaks of abundance.

2. A total of 76,400 spring chinook salmon, including 72,300 adults and 4,100 jacks was calculated to have migrated over Willamette Falls fishway in 1953.

3. The 1953 escapement surpassed that of any in recent years, and only the 53,000 escapement in 1946 and the 52,200 in 1952 approached this figure.

4. The last two cyclic returns (1947-52 and 1948-53) indicate increasing returns.

5. The average half-hourly counts indicated that the morning migration started at a slow rate, increased rather abruptly between 7:00 and 8:00 a.m., continued to increase gradually until about 2:00 p.m., and then remained at a relatively constant rate until the end of the counting period at 8:00 p.m. At the approach of darkness the migration fell off sharply.

6. Each night's migration was calculated to be 31.1 per cent of the preceding afternoon's count (noon—8:00 p.m.). This factor is based upon three 24-hour counts in 1953 and eight similar counts in previous years.

7. A sudden increase in the numbers of jacks counted accompanied the approach of the end of adult migration.

8. An estimated 1,200 steelhead passed over Willamette Falls during the period of counting, excluding the night migrations. Only the end of the run was recorded, so no estimation of the total escapement is available.

Acknowledgments

The methods and techniques followed in this report were originally evolved by Messrs. Donald L. McKernan and Donald R. Johnson. Mr. Chester R. Mattson assisted in gathering data and also offered advice and assistance in the preparation of this report. Thanks are also due to Mr. Marion G. Christensen for his cooperation in providing boat transportation for the fish counters. The counters were Messrs. Ralph E. Mooers and Gary T. Whittington.

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FOURTH PROGRESS REPORT ON SALMON DIET EXPERIMENTS[1]

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Introduction

The growth rate of fish is determined largely by water temperature, diet, and the age of the fish. Cold water is encountered in many salmon hatcheries in the Northwest, and the growth rate of fish in these localities is generally slow. An ideal place to conduct cold water experiments is at Marion Forks Hatchery, 17 miles southeast of Detroit, Oregon, on a small tributary of the North Santiam River. The elevation of the hatchery site is about 2,500 feet above sea level, and low water temperatures are encountered during most of the year.

The use of beef liver as a desirable fish hatchery food component was discussed in an excellent literature review by Karrick (1948). She also discussed the scarcity of beef liver as a hatchery food and the need for substitutes. Angersborg (1934) and Donaldson (1937) reported on the use

TABLE 1. **DESCRIPTION OF DIETS AND OBSERVATIONAL RESULTS**

Lot Number	Diet	Total Per Cent Gain	Observations
1	Control Beef liver 98%, salt 2%	21	Appetite poor. Growth moderate. Fish in fair condition. Easily frightened.
2	Salmon flesh 44%, salmon viscera 44%, beef liver 10%, salt 2%	34	Appetite good. Growth good. Fish in good condition. Lots 2, 3, and 4 contain same components in varying amount.
3	Salmon flesh 39%, salmon viscera 39%, beef liver 20%, salt 2%	31	
4	Salmon flesh 34%, salmon viscera 34%, beef liver 30%, salt 2%	36	
5	Shad flesh 30%, salmon viscera 48%, Argentine beef liver meal 20%, salt 2%	8	Appetite poor. Growth poor and lowest of all lots. Fish exhibited symptoms of B_1 deficiency. An inferior diet.
6	Salmon flesh 31%, salmon viscera 31%, beef liver 20%, salmon meal 12%, wheat germ 4%, salt 2%	38	Appetite fair. Growth good. Fish in good condition.

[1] Technical Paper No. 935, Oregon Agricultural Experiment Station.

of salmon meal and salmon by-products as food for young salmon. In spite of the good growth response reported, comparatively little salmon meal is used as a hatchery food.

An experiment was designed to evaluate several common hatchery foods for raising spring chinook salmon (*Oncorhynchus tshawytscha*) under cold water conditions. One control and five experimental diets were chosen (Table 1). The components included beef liver, Argentine beef liver meal, wheat germ meal, shad (*Alosa sapidissima*), and salmon (*O. tshawytscha*) flesh, salmon viscera, and salmon meal. Three diets were designed to study levels of beef liver that might be used to raise spring chinook salmon satisfactorily during periods of cold water. One diet was composed of shad flesh, beef liver meal, and salmon viscera. The final diet contained salmon and wheat germ meals in combination with salmon products and beef liver. These last two diets were preliminary evaluation tests and were not meant to be compared with each other or with the other four diets.

Procedure

The Marion Forks Hatchery is supplied with water from Marion and Horn Creeks. Horn Creek, which is spring fed and does not exceed 43° F. in summer or go below 36° F. in winter, was used as the water source in these experiments.

Six concrete circular ponds, each 25 feet in diameter, with a water depth of 18 inches, were used for the experiment. Each pond was stocked with 115 pounds of fish averaging 62 fish per pound, or approximately 7,100 fish per pond.

The experimental feeding was conducted for an 18-week period from December 7, 1950 to April 10, 1951. All lots were fed 3 or 4 times daily, 6 days a week. Each lot of fish received a daily allotment of food computed on a dry weight basis and equal to 1 per cent of the body weight (McKee, Sinnhuber, and Law, 1951). This procedure corrects for the variable water content of the food. All lots of fish received the same amount of dry food per unit of body weight.

All the food components with the exception of the meals were stored in a frozen condition. Only the amount needed for the day's ration was thawed before preparation of the diet. Diets were prepared each morning and any food unfed at the end of the day was weighed and discarded. Afternoon was found to be the best time to feed; warmer water at this time made the fish more receptive to food.

A sample of fish from each lot was weighed every 2 weeks during the experiment. After the fish were crowded into an area in the pond about 2 by 9 feet, approximately 10 per cent of the lot was sampled by lowering the water to a depth of 12 inches and sweeping a dip net from top to bottom the length of the restricted area. The net was allowed to drain approximately 10 seconds before the bottom was wiped twice to remove excess water. The sample was weighed and counted. At least three samples each containing approximately 10 per cent of the lot were taken on weigh days. The total weight of the lot was computed from these samples.

The beef liver was undenatured fluky beef liver obtained directly from the local packing house and brought to the Seafoods Laboratory at Astoria

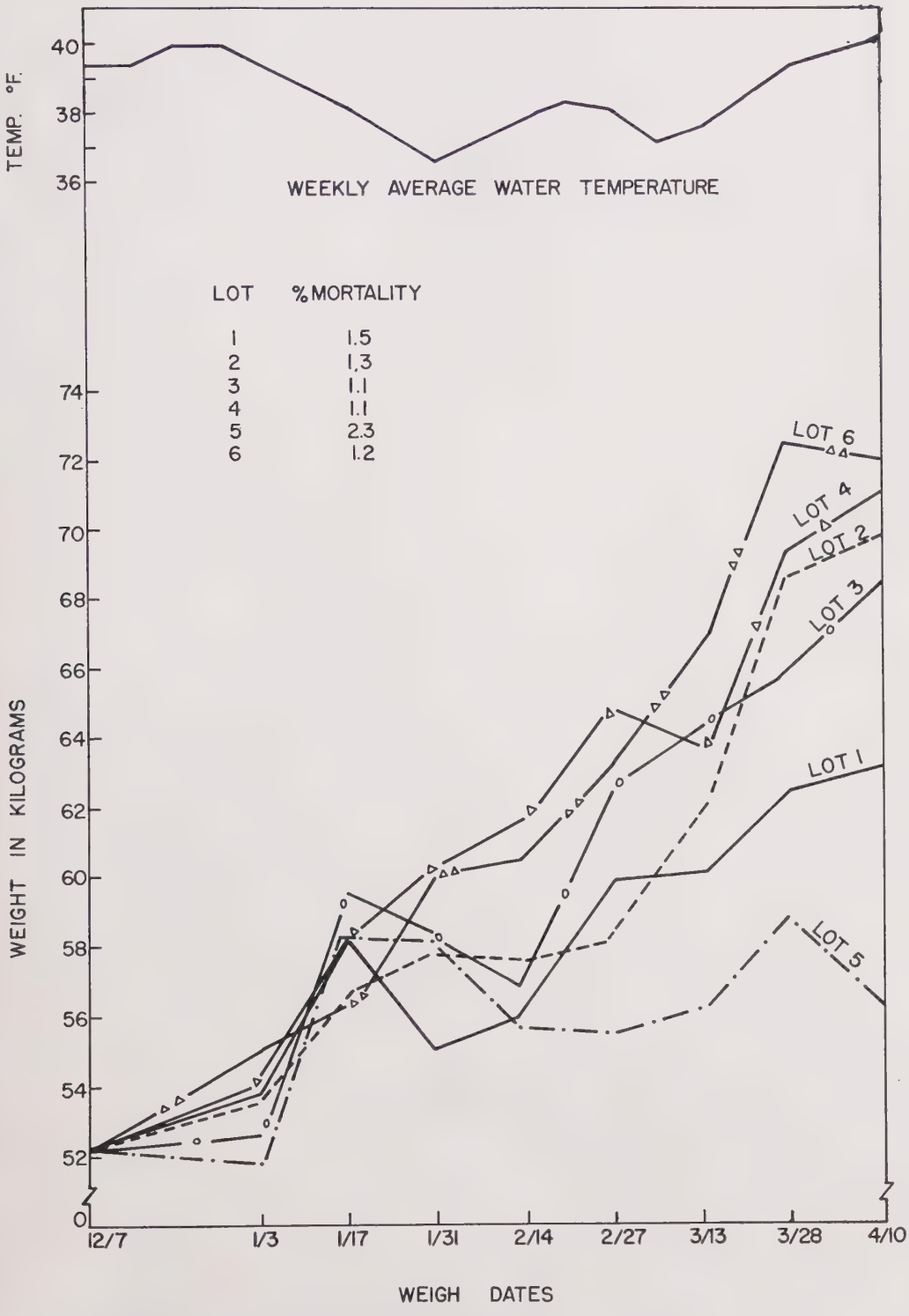

FIGURE 1. WEIGHT GAINS, PER CENT MORTALITY, AND WEEKLY AVERAGE WATER TEMPERATURE.

where it was ground, canned, and frozen. This is distinct from fluky beef liver that has been denatured and frozen at a packing house. The salmon flesh consisted of carcasses of spawned-out fall chinook salmon from the egg-taking operation at Bonneville Hatchery in 1950. This material was coarse-ground at Bonneville, placed in 50-pound boxes, and frozen. The salmon viscera was from the stock food supply at Marion Forks Hatchery and contained no heads, tails, or fins. The shad flesh, which was received frozen in 50-pound boxes, was prepared and ground at Bonneville Hatchery. The beef liver meal, a commercial product of Argentina, was purchased in Seattle. The wheat germ meal as well as the salmon meal, which is a commercially prepared product, were purchased locally.

Results

The component percentages by weight of each of the six diets, the observational results, and the total per cent gain for each diet are given in Table 1.

The biweekly weight gain and total per cent mortality for the individual lots as well as the weekly mean water temperatures are shown in Figure 1. The weekly mean water temperature did not exceed 40° F. No disease was encountered during the experiment. The losses in all lots were extremely low.

Conclusions

The control diet, 98 per cent beef liver with 2 per cent salt, provided only moderate growth under cold water conditions.

There appeared to be little correlation between the amount of beef liver fed and the resulting growth under the conditions of this experiment (Figure 1). However, the lowest level of beef liver fed, 10 per cent with other components, provided good growth. This is an important observation since beef liver is an expensive hatchery food and the supply is limited.

A diet containing Argentine beef liver meal and 30 per cent shad provided poor growth. The fish were sluggish and in poor condition. This may be due to the presence of the vitamin B_1 destroying enzyme, thiaminase, in shad. Shad is a member of the herring family and several members of this group are known to contain thiaminase.

A diet containing salmon meal and wheat germ meal in conjunction with other hatchery food ingredients gave good growth.

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MIGRATIONS OF STARRY FLOUNDER *(Platichthys stellatus)* TAGGED IN THE COLUMBIA RIVER

SIGURD J. WESTRHEIM

Introduction

The Washington State Department of Fisheries and the Fish Commission of Oregon jointly operated a fish trap on the lower Columbia River during 1951-53 to tag salmon and steelhead trout which enter the Columbia River. Other species of fish such as shad (*Alosa sapidissima*), sturgeon (*Acipenser transmontanus* and *A. medirostris*), and starry flounder (*Platichthys stellatus*) also entered the trap and were tagged as time permitted.

This report deals with the results obtained from the intermittent tagging of starry flounder and includes all tags returned by December 31, 1954.

Materials and Methods

The fish trap was initially installed along the Washington shore of the lower Columbia River about 5 miles upstream from the mouth (Figure 1).

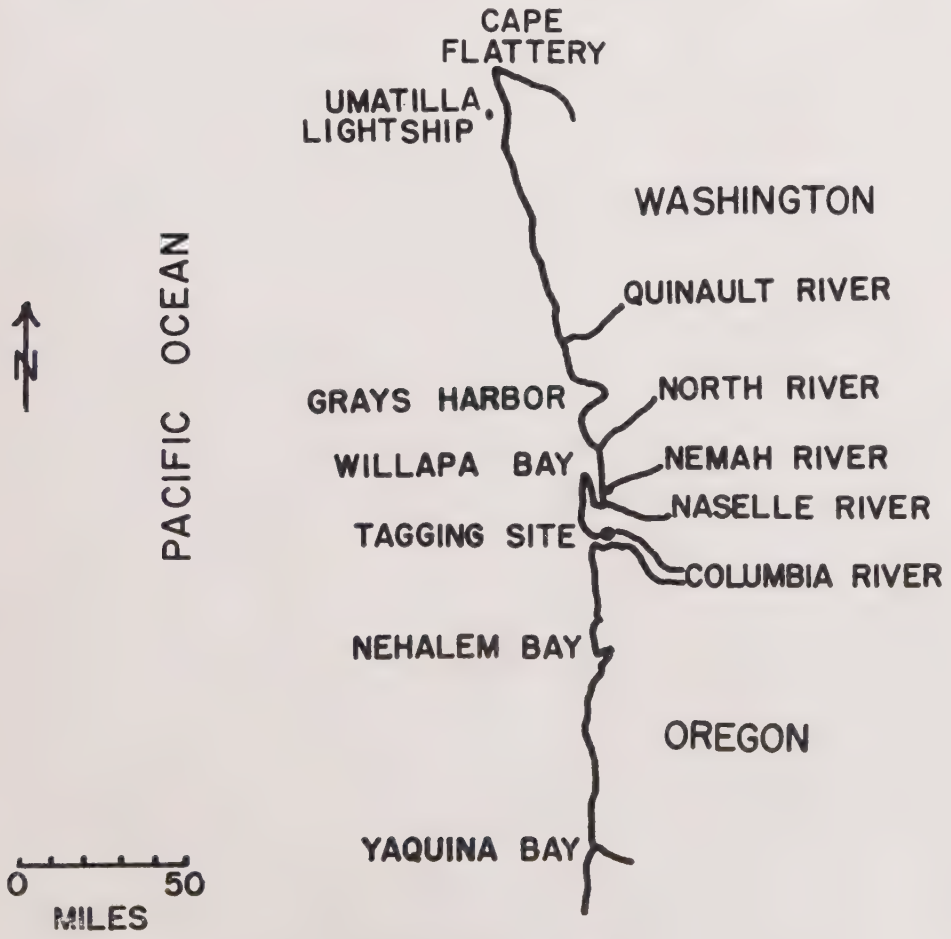

FIGURE 1. CHART OF OREGON AND WASHINGTON COASTLINES.

It was operated at this site during the autumn of 1951. Subsequently, a new site was selected 3 miles farther upstream near McGowan. The trap was operated at this new location during 1952 and 1953. Operations terminated November 14, 1953.

The flounder were tagged with plastic, Petersen-type disks which were affixed to the fish beneath the base of the dorsal fin midway along the body by means of a stainless steel or nickel pin. The total length, to the nearest inch, of each tagged fish was recorded before release.

No special efforts were expended to recover tagged fish nor was a reward offered for the tags, although reasonably well advertised programs were conducted in 1948 and 1949 for other species in the otter-trawl fishery. Salmon tagging has been almost continuous since 1947 and a sustained sampling program for tags and marks in the river gill-net fishery has been underway since the tagging began. The routine sampling of gill-net catches for tagged or fin-marked salmon and steelhead undoubtedly increased the number of recoveries of tagged flounder received.

Results

A total of 1,846 starry flounder was tagged, of which 111 (6 per cent) were subsequently recovered through 1954. The numbers tagged and recovered by month and year of tagging are presented in Table 1.

TABLE 1. **NUMBERS OF FLOUNDER TAGGED AND RECOVERED BY MONTH AND YEAR OF TAGGING, 1951-1953**

	YEAR OF TAGGING						*TOTAL*		
	1951 Numbers		*1952 Numbers*		*1953 Numbers*		*Numbers*		*Per Cent*
	Tagged	*Recovered*	*Tagged*	*Recovered*	*Tagged*	*Recovered*	*Tagged*	*Recovered*	*Recovered*
January	.....	.....	.....	.....	.....	.....	.....	.....	.....
February	.....	.....	.....	.....	.....	.....	.....	.....	.....
March	.....	.....	.....	.....	50	4	50	4	8
April	.....	.....	.....	.....	295	20	295	20	7
May	.....	.....	32	0	151	8	183	8	4
June	.....	.....	59	2	70	1	129	3	2
July	.....	.....	207	11	117	5	324	16	5
August	.....	.....	102	3	116	11	218	14	6
September	138	11	.....	.....	90	5	228	16	7
October	17	3	.....	.....	318	22	335	25	7
November	16	3	.....	.....	68	2	84	5	6
December	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total	171	17	400	16	1,275	78	1,846	111	6

Tagged flounder were recovered inside and outside the Columbia River. There were 85 recoveries (77 per cent of the total) from inside the Columbia River (Table 2). The maximum distance migrated from the tagging site for an inside recovery was 15 miles upstream. Virtually all of the inside recoveries were made within 10 miles of the fish trap.

There were 26 (23 per cent of the total) recoveries from outside the Columbia River. The outside area extended from a point within Yaquina Bay (125 miles from the tagging site in a southerly direction) on the central Oregon coast to the Umatilla Lightship (130 miles north of the tagging site) off the northern Washington coast. However, 18 of these recoveries were taken on the local otter-trawl grounds near the mouth of

TABLE 2. **NUMBERS OF TAGGED FLOUNDER RECOVERED BY TYPE OF FISHING GEAR, BY AREA, 1951-1954**

RECOVERY AREA	RECOVERY GEAR				
	Gill Net	*Fish Trap*	*Otter Trawl*	*Sport Troll*	*Total*
OUTSIDE COLUMBIA RIVER					
Local ①	0	0	18	0	18
Yaquina Bay	1	0	0	0	1
Nehalem Bay	1	0	0	0	1
Willapa Bay	3	0	0	0	3
Grays Harbor	0	0	0	1	1
Quinault River	1	0	0	0	1
Umatilla Lightship	0	0	1	0	1
TOTAL OUTSIDE COLUMBIA RIVER	6	0	19	1	26
TOTAL INSIDE COLUMBIA RIVER	68	16	0	1	85
GRAND TOTAL	74	16	19	2	111

① Local refers to otter-trawl grounds near the mouth of the Columbia River which are 10 to 25 miles from the tagging site.

the Columbia River, 10 to 25 miles from the tagging site. Single recoveries were made in Yaquina Bay, Nehalem Bay, Grays Harbor, Quinault River, and near the Umatilla Lightship. Three recoveries came from Willapa Bay.

The tagged flounder were recovered from a variety of fishing gear. Salmon gill-nets took 74, otter-trawl nets, 19; fish traps (tagging sites), 16; and salmon sport fishermen, 2 (Table 2).

Figure 2 presents the numbers of tagged flounders in each one-inch size interval together with the numbers subsequently recovered from the same size intervals.

The size range of the tagged flounder was 6 to 27 inches. The modal size group was 11 inches, and the mean length was 12.4 inches.

The mean length, when tagged, of the recaptured flounder for all areas and gear, was 13.4 inches (Table 3). Segregation of the recoveries by general area of recapture, i. e., inside and outside the Columbia River, produced mean lengths (at time of tagging) of 12.6 inches for inside recoveries and 15.3 inches for outside recoveries. This difference is thought to be due in part to the selectivity of the otter-trawl gear which captured the majority of the outside recoveries.

The range of days out before recapture was 1 to 735 for all recoveries. For inside recoveries the range was 1 to 650, and 61 per cent of these

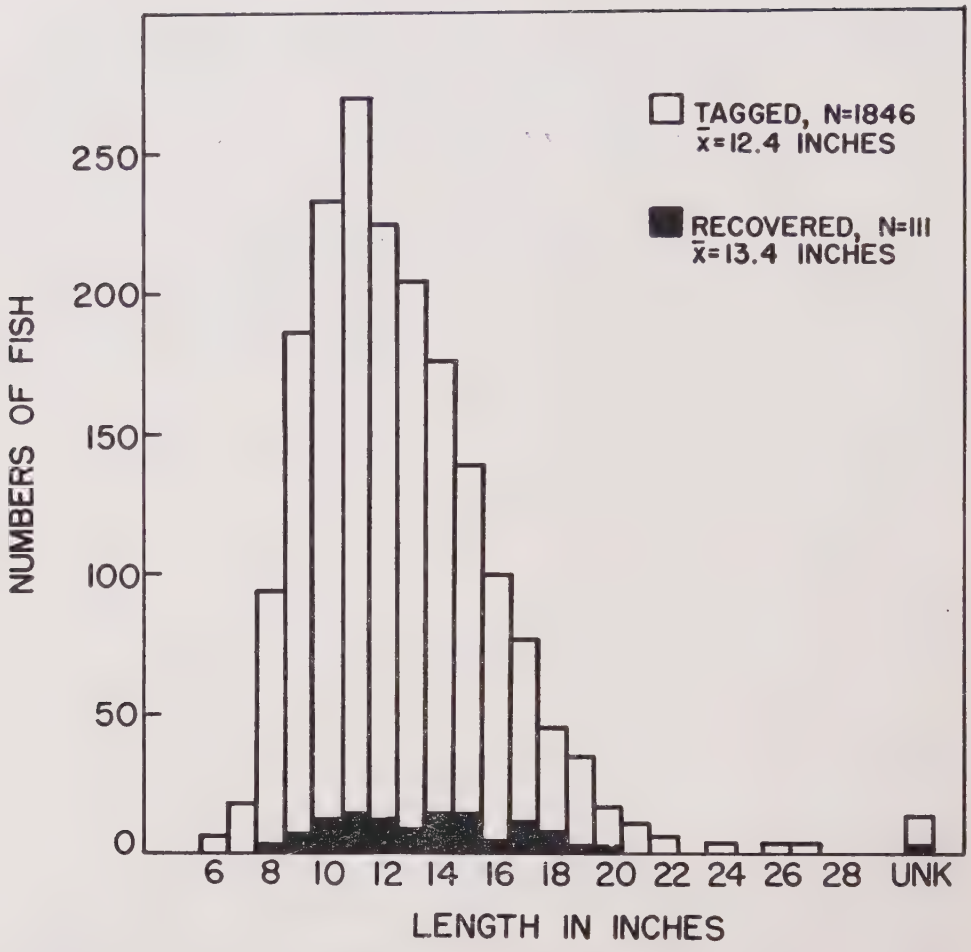

FIGURE 2. NUMBERS OF FLOUNDER TAGGED AND RECOVERED, BY SIZE AT TAGGING.

recaptures were taken less than 60 days after tagging. For outside recoveries the range was 9 to 735 days out, and 31 per cent were taken less than 60 days after tagging.

TABLE 3. **MEAN LENGTHS AT TIME OF TAGGING OF TAGGED AND RECOVERED FLOUNDER**

Tagging Year	*MEAN LENGTH (Inches)*			
	Tagged Fish	*Recovered Fish*		
		Inside Columbia R.	*Outside Columbia R.*	*Total*
1951	11.8	11.9	15.0	13.5
1952	11.7	11.3	15.5	12.0
1953	12.6	13.1	15.5	13.7
Total	12.4	12.6	15.3	13.4

Several tagged flounder traveled considerable distances after tagging before suffering recapture. Some insight into their rate of migration has been obtained by considering only those recaptured outside the Columbia River in areas other than the local trawling grounds. This limitation restricts the study to 8 fish (Table 4). The range in miles traveled was

TABLE 4. **MILES TRAVELED, DAYS OUT, AND MILES PER DAY, FOR EIGHT TAGGED FLOUNDER RECOVERED OUTSIDE THE COLUMBIA RIVER**

Tagging Year	*Recovery Area*	*Miles Traveled* ①	*Days Out*	*Miles Per Day*
1951	Willapa Bay (Naselle River)	55	23	2.4
1952	Nehalem Bay	45	102	0.4
1953	Yaquina Bay	125	58	2.2
	Willapa Bay (Nemah River)	50	9	5.6
	Willapa Bay (North River)	45	20	2.3
	Grays Harbor	60	466	0.1
	Quinault River	75	38	2.0
	Umatilla Lightship	130	98	1.3

① Nautical miles.

45 to 130, and in days out, 9 to 466. The most frequent minimum rate of travel was approximately 2 miles per day, and the range was 0.1 to 5.6 miles per day. It is realized that the fish were at the place of recapture an undetermined length of time before being retaken.

Summary

A total of 1,846 starry flounder was tagged during 1951-53 from a fish trap on the lower Columbia River near Chinook, Washington. Recaptures totaled 111 or 6 per cent by December 31, 1954.

Recoveries were made inside (85) and outside (26) the Columbia River. The inside recoveries were all taken within 15 miles of the tagging site. The outside recoveries were taken 10 to 130 miles from the tagging site. The southernmost recapture occurred in Yaquina Bay on the central Oregon coast, 125 miles from the tagging site. The northernmost recapture occurred near the Umatilla Lightship on the northern Washington coast, 130 miles from the tagging site.

The recoveries by gear were as follows: salmon gill-nets, 74; otter-trawl nets, 19; fish traps (tagging sites), 16; and salmon sport fishermen, 2.

Days out after tagging ranged from 1 to 735 days, although 61 per cent of the inside recoveries and 31 per cent of the outside recaptures took place less than 60 days after tagging.

The rate of migration ranged from 0.1 to 5.6 miles per day for the 8 outside recaptures taken in areas other than the local otter-trawl grounds off the Columbia River. The most frequent minimum rate was approximately 2 miles per day.

Acknowledgments

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